A ROBUST SIGNALLING SYSTEM FOR LAND MOBILE SATELLITE SERVICES

DALE IRISH, GARY SHMITH, NICK HART, MARIE WINES
AUSSAT Mobile Services, Australia

AUSSAT Pty Ltd
GPO Box 1512
Sydney NSW 2001
Australia

ABSTRACT

This paper presents a signalling system optimised to ensure expedient call set-up for satellite telephony services in a land mobile environment. In a land mobile environment, the satellite to mobile link is subject to impairments from multipath and shadowing phenomena, which result in signal amplitude and phase variations. Multipath, caused by signal scattering and reflections, results in signal level variations of 5 dB or less. It is feasible to provide sufficient link margin to compensate for these variations. Direct signal attenuation caused by shadowing due to buildings and vegetation may result in attenuation values in excess of 10 dB and commonly up to 20 dB. It is not practical to provide a link with sufficient margin to enable communication when the signal is blocked. When a moving vehicle passes these obstacles, the link will experience rapid changes in signal strength due to shadowing. Using statistical models of attenuation as a function of distance travelled, a communication strategy has been defined for the land mobile environment.

PROPAGATION MEASUREMENTS

Propagation measurements conducted in Sydney [1] and Melbourne [2] have recorded signal amplitude and phase as a function of distance travelled in various land mobile environments. Propagation data has been averaged to remove rapid signal level variations caused by thermal noise. A running average was taken using an average interval of 5 ms (70 cm at 50 kph). Analyses have resulted in cumulative fade duration distributions and block error probabilities. Additionally, conditional block error probabilities (the probability that a block error will reoccur after a given delay) have been calculated. Results are presented as a function of threshold value, block size and delay. A threshold of 7 dB below the line-of-sight signal level has been considered to reflect the edge of coverage link margin for the proposed MOBILESAT signalling system. A study by SAIT [3] of bit error performance of the proposed Reed Solomon code has determined that the coding can compensate for threshold crossings of 1 ms on a 9600 sps link and 4 ms on a 2400 sps link. Analysis of data with resolution of 5 ms calculates block errors caused by fades which cannot be compensated by the specified coding.

Figures 1 and 2 graphically illustrate cumulative fade and nonfade duration as a function of signal level threshold for experimental runs labelled 401-407. Runs 401 and 402 represent data taken while

PRECEDING PAGE BLANK NOT FILMED

travelling in opposite directions on a road with a medium degree of shadowing from individual toll trees. Runs 406 and 407 represent data taken on a road with a greater degree of shadowing from groups of toll trees. These runs were selected to characterise medium to heavily shadowed areas, which are common in rural Australia. AUSSAT has set a performance objective of providing expedient call set up on roads where the signal is above the link threshold for more than 90% of the distance travelled. Referring to Figure 2, experimental run 407 is just within this criteria for a link margin of 7 dB. Experimental run 406 fails to meet this objective.

Analyses of block error probability show a strong dependence on block size. The results indicate that to combat rapid shadowing it is necessary to minimise the burst length. AUSSAT proposes to use the highest data rate and shortest burst length practical within power and bandwidth constraints. Simulations have shown that unacceptable delays may still occur and therefore the benefits of transmitting multiple repeats of signalling information have been investigated. A marked improvement in successful transmission is evident when information is repeated within one second. TELECOM [2] have demonstrated that additional improvement is quite small when the transmission delay is increased above one second.

THE MOBILESAT SIGNALLING SYSTEM

AUSSAT required a simple and robust signalling system that could meet the following design criteria:

(i) Support a population of 100,000 terminals in a single beam system
(ii) Support a call set up rate of 6 calls per second with additional user messaging and system overheads
(iii) Provide system modularity to support future requirements and growth (eg multiple beams)
(iv) Enable system performance verification

Using the conclusions of the propagation analyses, AUSSAT has designed a robust signalling system and call set up protocol. AUSSAT will release a full system specification in July 1989. A description of the signalling links follows and is illustrated in Figures 3 and 4.

Outbound Signalling Link

A high power outbound signalling link will be transmitted using BPSK modulation at a symbol rate of 9600 sps. The high data rate simplifies the requirements of carrier acquisition by mobile terminals and provides the capacity to support multiple repeats of signalling information on a single channel. Transmitting at a high data rate has the effect of decreasing packet length, thus decreasing the probability that packets will suffer corruption.

TDM packets are based on a standard signalling unit with a length of 96 bits. Each SU is coded with a rate 3/4 Reed Solomon code using (16/12) coding with 8 bits forming a RS code symbol. The resulting TDM packet is therefore 128 bits (13.3 ms) in length.

The channel will be based on a 110 ms frame length. Each frame is composed of a 32 bit unique word for frame synchronisation, followed by eight contiguous TDM packets. A superframe format that includes three repeats of signalling information within 1100ms has been derived using conditional block error probabilities. Figure 3 illustrates the proposed superframe format, with three repeats of all signalling packets occurring in the 1100 ms superframe. A single outbound channel supports 24 signalling units and repeats in a single superframe. The NMS operator will be able to adapt the superframe length and number of repeats of specific packets to match operational experience or changing requirements. A mobile terminal will recognise only basic frame and packet sequence numbers and is therefore not affected by the superframe format.

Inbound Link

Inbound channels are transmitted at a symbol rate of 2400 sps. Bursts occur in independent 110 ms slots and are synchronised to the outbound channel. Inbound signalling packets are comprised of a 32 bit preamble, a 32 bit unique word and a 96 bit signal unit. Coding is identical to that of the outbound channel. The resulting burst is 80 ms in length. Figure 4 illustrates the proposed channel format.

The request protocol applied to the telephony service is designed to minimise call set-up time. Slotted ALOHA is the random access protocol used to support a large population of bursty users. The allocation of random access channels will meet the expected load. It is proposed that this protocol operate without a collision resolution algorithm, to eliminate double hop delays necessary for slot state feedback. Sufficient request channels will be necessary to maintain system stability and throughput. Yan and Clare [4] have demonstrated that repetition of requests can improve delay and throughput performance when operating in fading conditions.

The protocol for acknowledgements of outbound signalling messages and responses to polling commands uses a reserved access TDMA scheme. A symmetric relationship exists between inbound and outbound channels. On a per frame basis, eight inbound channels can transmit the equivalent number of signalling messages as one outbound channel. Therefore, each outbound signalling message has an inbound slot assigned to it for the return of an acknowledgement. To reduce the number of inbound channels required, a number of outbound slots may be reserved for messages that do not require acknowledgement.

PERFORMANCE EVALUATION OF THE MOBILESAT SYSTEM

To quantify the effect of time diversity on signalling message throughput, AUSSAT has simulated the links with one, two and three attempts offset in accordance with the proposed superframe format. The offsets used in the analysis are as follows:

- Outbound TDM Channel (9600 bps) ---> 317 ms
- Inbound Channel (2400 bps) ---> 220 ms

If any of the repeats remains uncorrupted, the signalling message is flagged successful. Figures 5 and 6 illustrate that the proposed repeat protocol achieves an outbound signalling message throughput of 99% for experimental run 407, which was identified in Section 2 as falling just within the stated performance objective.

CONCLUSION

The philosophy adopted in the design of the MOBILESAT signalling system has been to provide a robust solution to the problems encountered in a land mobile satellite channel. Simulations of the current design have demonstrated an outbound signalling packet throughput of at least 99% in a medium to heavily shadowed channel. Simulations have also shown a significant improvement in inbound signalling packet throughput via the use of repeats. A reliably high packet throughput enables a simple call set up protocol that reduces handshaking and hence minimises call set up time.

Figure 1: Cumulative Fade Distribution

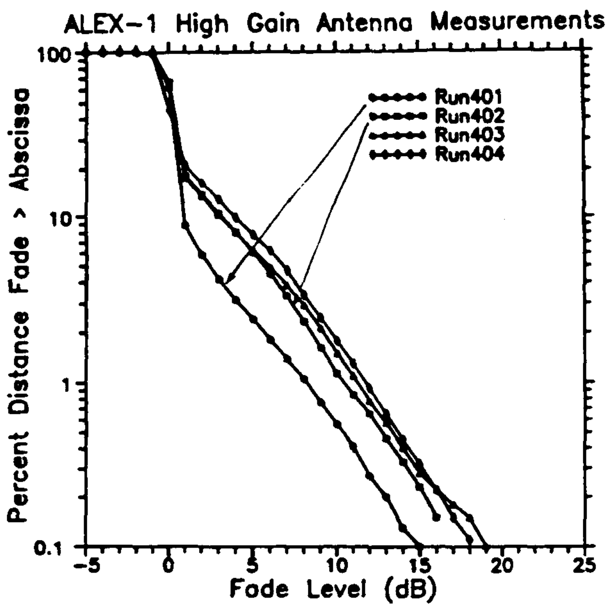
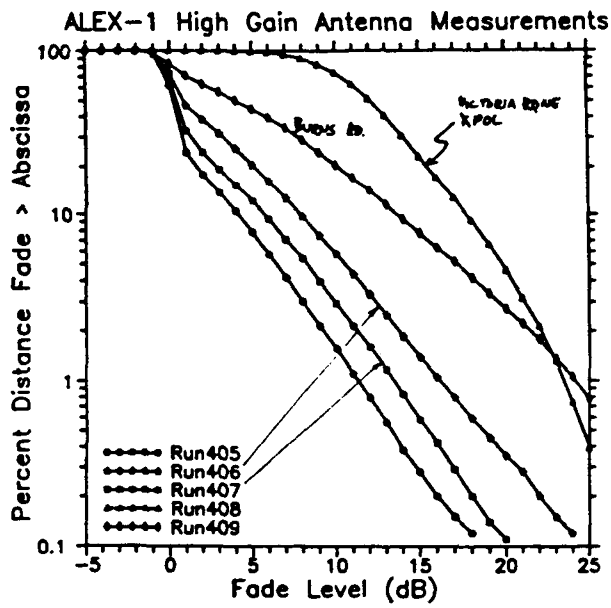


Figure 2: Cumulative Fade Distribution



REFERENCES

[1] W Vogel, Results from Propagation Measurements in Sydney, as yet unpublished.

[2] I T Hawkes, Land Mobile Satellite Transmission Measurements at 1550 MHz, Telecom Research Laboratories publication, Jan 1989.

[3] Progress Report, Mobile Satellite Communication Systems: Structures and Networks, South Australian Institute of Technology, Digital Communications Group, Feb 1989.

[4] T-Y Yan, L P Clare, Performance Analysis of Replication ALOHA for Fading Mobile Channels, IEEE Trans Communications, Vol Com-34, No 12, Dec 1986.

Figure 3

TDM SUPER FRAME FORMAT

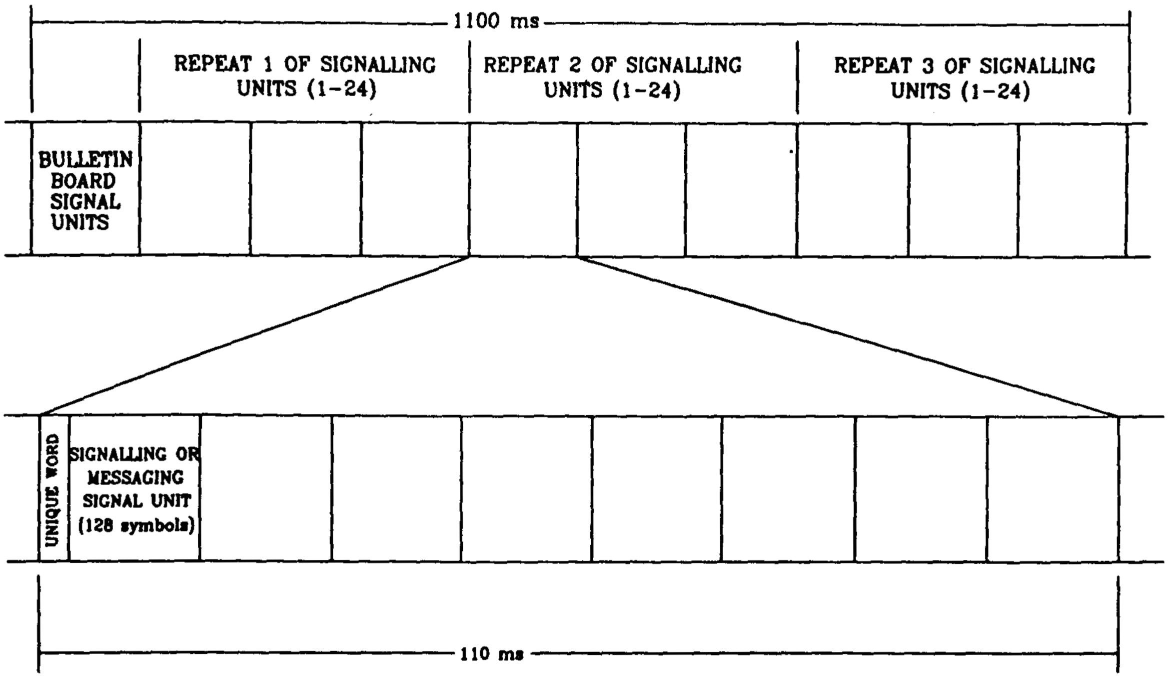


Figure 4

INBOUND SIGNALLING AND MESSAGING FORMAT

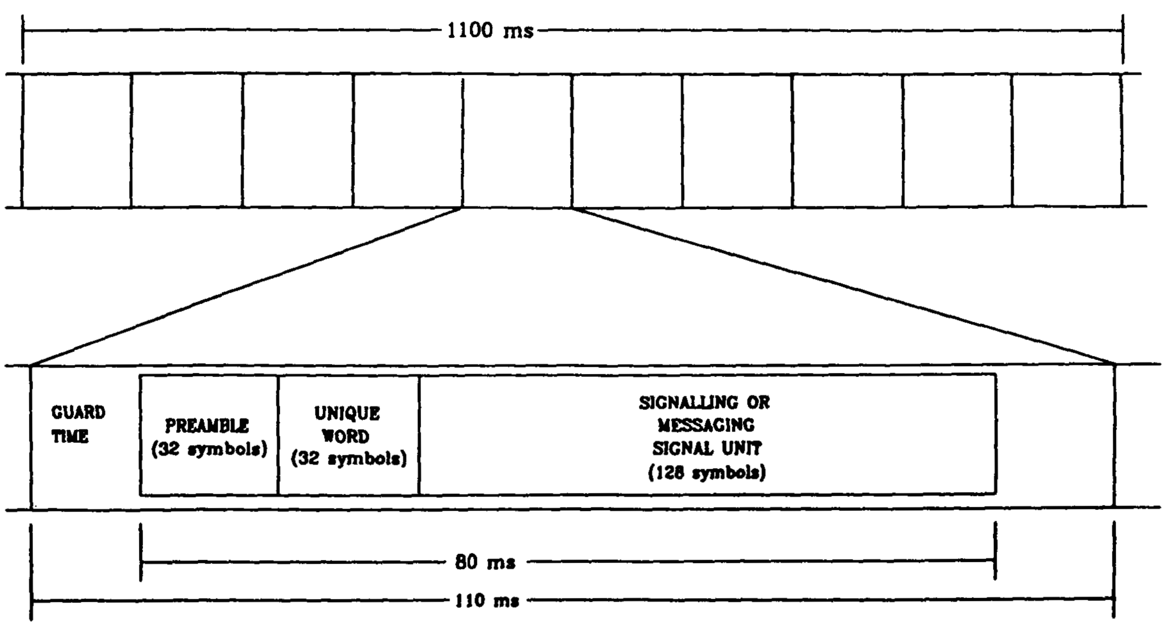


Figure 5

ETS-V HIGH GAIN ANTENNA DATA

OUTBOUND SIGNALLING INFO. FADING STATS.

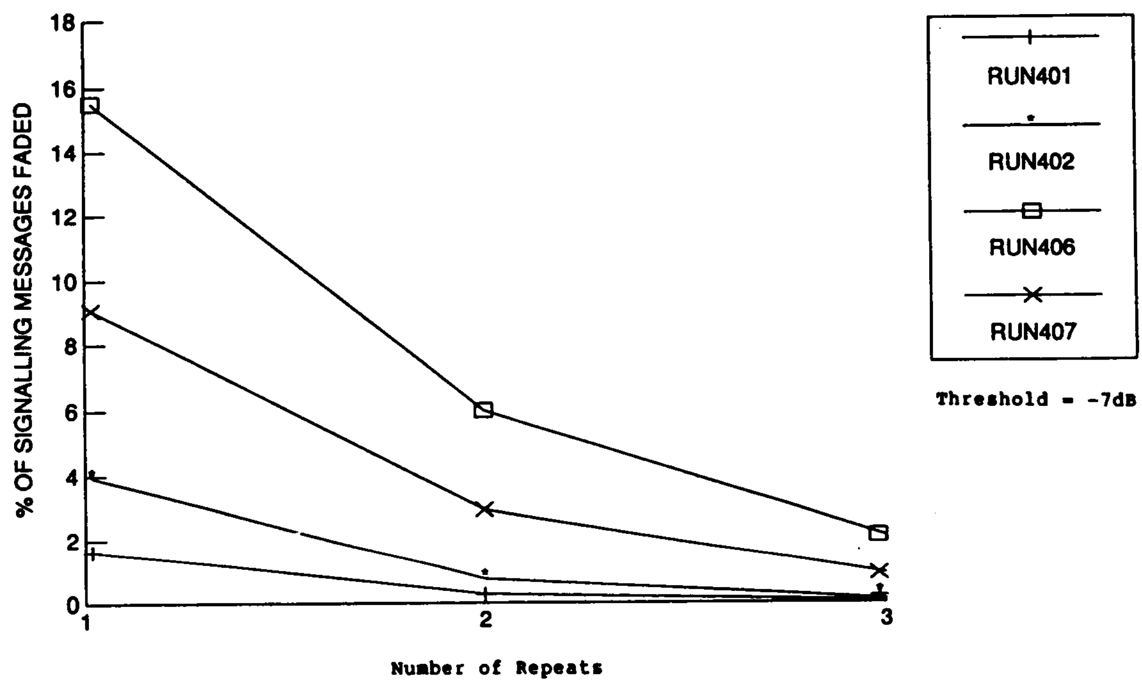


Figure 6

INBOUND SIGNALLING INFO. FADING STATS.